# Elevating Baseline Activation does not Facilitate Reading of Unattended Words

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## Abstract

Previous studies have disagreed the extent to which people extract meaning from words presented outside the focus of spatial attention. The present study, examined a possible explanation for such discrepancies, inspired by attenuation theory: unattended words can be read more automatically when they have a high baseline level of activation (e.g., due to frequent repetition or due to being expected in a given context). We presented a brief prime word in lowercase, followed by a target word in uppercase. Participants indicated whether the target word belonged to a particular category (e.g., “sport”). When we drew attention to the prime word using a visual cue, the prime produced substantial priming effects on target responses (i.e., faster responses when the prime and target words were identical or from the same category than when they belonged to different categories). When prime words were not attended, however, they produced no priming effects. This finding replicated even when there were only 4 words, each repeated 160 times during the experiment. Even with a very high baseline level of activation, it appears that very little word processing is possible without spatial attention.


**Keywords: Semantic Activation, Word Recognition, Spatial Attention, Priming Effects**

**Elevating Baseline Activation does not Facilitate Reading of Unattended Words**

Can visual objects be identified without spatial attention? For example, could a driver attending to another car read a passing road sign? This question has generated a large literature, in large part because it is central to how we characterize human visual attention (e.g., whether visual information processing is serial or parallel). The present study focused on the role of spatial attention in semantic activation from words because word reading is an important activity in our daily life. In particular, we examined whether elevating the baseline level of activation, by repeating a small set of target words, would induce automatic word processing in the absence of spatial attention.

**Spatial Attention in Word Processing**

The role of spatial attention in word processing has long been a contentious issue (see Neely & Kahan, 2001, for a review). Most studies have used some variant of a priming paradigm. In such a paradigm, a word (which we will refer to as the prime), requiring no response, is presented simultaneous with or immediately preceding a target word to which a speeded response is made. It is well-documented that, when the prime is attended, participants respond faster to related targets than to unrelated targets. In the lexical-decision task (word vs. non-word), for instance, participants are faster to indicate that the target is a word (e.g., “butter”) when an attended prime is a related word (e.g., “bread”) rather than an unrelated word (e.g., “nurse”). This phenomenon is known as the priming effect (e.g., Meyer & Schvaneveldt, 1971; see Neely, 1991, for a review). Similarly, people are slower to name the color of a bar if the name of a different color is printed nearby (the Stroop effect; e.g., Stroop, 1935; see MacLeod, 1991 for a review). The critical question addressed here is whether primes also influence target processing when they are completely unattended. Some studies have suggested that spatial

attention plays little or no role in semantic activation during word processing (e.g., Brown, Gore, & Carr, 2002; Fuentes, Carmona, Agis, & Catena, 1994; Fuentes & Tudela, 1992; Heil, Rolke, & Pecchinenda, 2004; LaBerge & Samuels, 1974; Siéroff & Posner, 1988), while others have indicated an important role of spatial attention (e.g., Besner, Stolz, & Boutilier, 1997; Chiappe, Smith, & Besner, 1996; Dark, Johnston, Myles-Worsley, & Farah, 1985; Stolz & Besner, 1999; Stolz & McCann, 2000; Stolz & Neely, 1995; Stolz & Stevanovski, 2004).

In an attempt to resolve the controversy, Lachter, Forster, and Ruthruff (2004) recently noted that some demonstrations of semantic activation outside spatial attention might actually be due to slippage of attention to the supposedly unattended words. That is, the so-called unattended condition might actually involve spatial attention to the primes on some or most trials. After taking several steps to reduce or eliminate unwanted attentional slippage, they eliminated priming effects from distracters in a lexical-decision paradigm.

Although Lachter et al. (2004) might be correct in warning about the possibility of attentional slippage, slippage might not explain all cases of semantic activation of unattended words. It has long been noted that the Stroop paradigm produces very robust interference effects (for a review, see MacLeod, 1991), even when the color word is spatially separated from the colored stimulus, reducing incentive to attend it (e.g., Brown et al., 2002; Dyer, 1973; Gatti & Egeth, 1978). Lachter, Ruthruff, Lien, and McCann (2008) recently demonstrated that these Stroop effects persist even when taking the steps recommended by Lachter et al. (2004) to prevent attentional slippage to color words. For example, they (a) presented colored targets in a fixed location, promoting endogenous attention to the target location, (b) flashed colored stimuli in the target location to capture attention endogenously, and (c) presented the irrelevant color words so briefly (50 ms) that they had no time to capture attention prior to being extinguished

and masked. Despite these steps, they found significant Stroop effects (about 14 ms Experiment 1 and 13 ms in Experiment 2). They even found small but reliable Stroop effects (~4 ms) when the words were not color words but merely associated semantically with particular colors (e.g., "crimson" for red, and "pea" for green). They concluded that although spatial attention certainly facilitates semantic activation and increases Stroop effects, it is not absolutely essential in the Stroop color-naming paradigm.

**Automaticity Induced by Elevated Baseline Activation**

Why does semantic activation seem to be possible in the Stroop color-naming paradigm (Lachter et al., 2008), but not in the lexical-decision paradigm (Lachter et al., 2004)? Note that Stroop experiments typically present each of 4 color words numerous times during a session, whereas lexical-decision experiments typically present each word only once. This observation raises the intriguing hypothesis that repeating words heightens the baseline activation which, in turn, increases the automaticity of word recognition. It could also explain previous observations from the dichotic listening paradigm that people often notice their own name in an unattended channel (Moray, 1959).

This hypothesis resembles Treisman's (1960) attenuation theory, which proposes that the processing of unattended stimuli is merely attenuated rather than being filtered out entirely. Words that are familiar (such as one's own name) or highly probable within a particular context might have an elevated baseline level of activation, allowing them to reach for the threshold for conscious recognition despite some attenuation. It is not clear that this simple mechanism can explain the results from more recent priming studies, however. Priming effects from attended stimuli occur even when participants are unaware that any primes are being presented (e.g., Forster & Davis, 1984). For a prime to be effective and produce an effect on the target

processing, it need only increase the activation of the associated representation (without necessarily reaching consciousness), so that the subsequent target word can reach the threshold faster. The traditional attenuation theory asserts that all stimuli, even unattended ones, receive some processing; hence, all stimuli should produce substantial priming effects, even those that never reach consciousness. As noted above, this is clearly not the case in the lexical-decision paradigm (e.g., Lachter et al., 2004).

The theory proposed in the present study therefore departs from the traditional version of the attenuation theory. Instead of proposing a reduced threshold for reaching consciousness, we propose that repeating words increases the rate at which semantic activation accumulates. Specifically, we propose that high baseline activation levels enable activation to accumulate even for completely unattended stimuli.

There is already evidence that, for attended words, expectation does enhance stimulus processing. Ballard (1991) noted that, while it is computationally difficult to simultaneously identify multiple objects, it is much easier to identify a particular object in the world, or find one matching a particular internal representation. A number of neurophysiological studies suggest a mechanism that might implement the ability to find expected objects (e.g., Fuster, 1990; Fuster & Jervey, 1982; Haenny, Maunsell, & Schiller, 1988; Maunsell, Nealey, Sclar, & DePriest, 1989; Miyashita & Chang, 1988). In particular, these studies found cells in areas V4 (an area thought to be important in visual attention) and IT (an area thought to be important in object recognition) of macaque cortex that respond to what the monkey is looking for rather than what it is looking at. Such representations must serve to aid relatively low-level visual mechanisms in finding particular items. A few divided-attention experiments point in a similar direction. For example, Rossi and Paradiso (1995) had participants judge the spatial frequency and orientation

of a Gabor patch. On one third of trials, participants were asked to determine whether a sinusoidal grating had appeared in the background. They were better at detecting sinusoids near the orientation of the Gabor patch when their primary task was to judge the orientation of the Gabor patch and were better at detecting sinusoids near the spatial frequency of the Gabor patch when their primary task was to judge the spatial frequency of the Gabor patch. In other words, a feature in the background was more easily detected when it matched the feature the participant was attending to.

In summary, it is highly plausible that elevating the baseline activation of words facilitates the recognition of attended words. These studies do not, however, directly bear on the present hypothesis that high baseline activation levels facilitate the automatic recognition of <u>unattended</u> words.

## The Present Study

The present study was designed to examine whether semantic activation outside spatial attention is possible when the baseline activation level of words are elevated due to repeated presentation. If so, the results would help reconcile the discrepancy between different lines of experiments (lexical decision vs. Stroop). The results will also help to define the relationship between spatial attention and feature-based attention. If you are looking for a particular item in a particular location, will that item be noticed in another location that you are not attended to? The general research question is also of practical interest, because in many real-world contexts stimuli are frequent and expected. When reading text, for example, certain words occur more often than others, and/or are highly predictable within a certain context (e.g., “he put the pizza in the ___”). This might help readers to read quickly and more automatically, without needing to attend each word.

Instead of using a lexical-decision paradigm, we used a categorization paradigm. Participants simply indicated whether each word did or did not belong to a pre-specified category (following Lien, Ruthruff, Cornett, Goodin, & Allen, 2008). One motivation for using a categorization paradigm is that it makes it easy to manipulate the baseline activation of words by reducing the number of categories and the number of words per category. A further advantage of this categorization paradigm over the lexical-decision paradigm is that a word was used as a target for all trials rather than only half of the trials, as in the lexical-decision paradigm. Thus, the categorization paradigm would have twice as many trials to analyze compared to a lexical-decision paradigm.

For each participant, an uppercase target word was always presented in a fixed location (the top for half of the participants and the bottom for the other half; see Figure 1). Prior to the presentation of the target word, a lowercase prime word (to be ignored word) was presented in the opposite location. The critical manipulation was the semantic relationship between the prime word and the target word. There were three conditions, each equally likely to occur. In the *identical condition*, the prime word was the same as the target word (e.g., the word "jeans" for both the prime and target). In the *same category condition*, the prime word was different from the target word but was from the same category (e.g., the prime word "jeans" and the target word "shirt" when the category was "clothing"). In the *different category condition*, the prime word was from a different category than the target word (e.g., the prime word "jeans" and the target word "lime" when the category was "fruit"). Using response time (RT) and proportion of error (PE) data, we established two overlapping measurements of semantic activation: the identity priming effect and the semantic priming effect (see Equations 1 and 2). The identity priming effect is the most sensitive, but the semantic priming effect eliminates any contribution from

low-level perceptual priming.

$$\textit{Identity Priming Effect} = \textit{Different Category} - \textit{Identical} \qquad (1)$$

$$\textit{Semantic Priming Effect} = \textit{Different Category} - \textit{Same Category} \qquad (2)$$

As in Lachter et al. (2004, 2008), we took three steps to minimize attentional slippage. First, the prime was presented for only 50 ms, followed by a 50-ms mask (see Figure 1). The target appeared immediately after the offset of the mask; thus, the interval between the onsets of the prime and target words was only 100 ms. Second, the target location was fixed throughout the whole experiment for each participant, encouraging the endogenous allocation of attention to this location only (and not the location of the prime). Third, to manipulate the exogenous allocation of attention to a particular location, we used a cue consisting of a rapid sequence of three nonwords (uppercase, lowercase, and then uppercase). These cues were too brief to be processed deeply (25 ms), but were sufficiently target-like to capture spatial attention (e.g., Folk, Remington, & Johnston, 1992). On half of the trials, the cue drew attention to the target location. Thus, on these trials, both endogenous and exogenous attention worked together to keep attention away from the prime words. We therefore refer to this condition as *uncued* or *unattended prime*. On the other half of the trials, the cue drew attention to the prime location. We refer to this condition as *cued* or *attended prime*.

Experiment 1 measured the identity and semantic priming effects using a large set of 162 target words and each word repeated only 4 times within a session. Experiments 2 and 3 then examined whether both identity and semantic priming effects increase when the words are presented much more frequently within a session (8 target words repeated 80 times in Experiment 2 and 4 target words repeated 160 times in Experiment 3). We expect to obtain both identity priming effect and semantic priming effect when spatial attention directed to the prime

word (i.e., cued prime words). The main question is whether the identity and semantic priming effects will be obtained when spatial attention is directed away from the prime word (i.e., uncued prime words). If semantic activation outside spatial attention is possible only when word representations are already highly activated (i.e., due to repeated presentation within a session), then one would expect to obtain substantial priming effects that increase as the words are repeated more often within a session (i.e., increased from Experiment 1 to Experiment 3).

## Experiment 1

Experiment 1 measured priming effects when each word was presented only occasionally within a session. We used 18 different category lists, taken from Lien et al. (2008)[1]. Each category contained 18 words. To make the session length manageable, however, each participant received only 9 of these categories in 9 different experimental blocks. Within each block, half of the target words were related to the category and half were unrelated. Each of the 18 words belonging to that category was presented twice within the block. These words were also presented twice as the target during other blocks, when they were unrelated (using the same exact words for the related and unrelated conditions ensures that they are perfectly matched). Thus, overall, each word was presented 4 times as the target during the session for each participant.

### Method

Participants. Sixty undergraduate students from Oregon State University and the University of New Mexico participated in exchange for extra course credit. Their mean age was 19 years, with a range of 18 to 30 years. They were all native English speakers and had normal or corrected-to-normal vision. All included participants demonstrated normal color vision using the Ishihara color test.

Apparatus and Stimuli. Stimuli, presented on 19-inch monitors, were viewed from a distance of about 55 cm. All stimuli were presented in white against a black background. Each trial started with a fixation display, which consisted of a centrally-located plus sign (0.83° × 0.83°). As shown in Figure 1, each of the subsequent displays contained top and bottom rows of characters, which were centered 1.25° apart. The premask display consisted of two rows of hash marks ("########"). Each hash mark was 0.52° × 0.83°. The cue display consisted of one row of hash marks and a sequence of three nonwords printed in uppercase, lowercase, and then uppercase. The prime display consisted of hash marks in one row and a word printed in lowercase in a different row. The postmask display consisted of two rows of character strings ("%@$?$@%"). The target display consisted of character strings in one row and a word printed in uppercase in a different row. Each of the uppercase letters and symbols subtended a visual angle of approximately 0.73° wide × 0.83° high, whereas each of the lowercase letters subtended a visual angle of approximately 0.52° wide × 0.83° high.

Design and Procedure. Prior to each block, we presented a category word (e.g., "sports") on the screen. Participants were asked to remember the category word for that particular block. As shown in Figure 1, each trial started with the fixation display for 1,200 ms, followed by the premask display for 300 ms. The three cue displays then appeared sequentially for 25 ms each, followed by the premask display for 25 ms. The prime display then appeared for 50 ms, followed by the postmask display for 50 ms, and the target display for 500 ms. Thus, the interval between the onsets of the prime display and the target display was 100 ms. The participants' task was to indicate whether the uppercase target word was semantically related or unrelated to the category word presented on the screen prior to each block (e.g., the target word "GOLF" would be semantically related to the category word "sports" but the target word "PLUM" would

be unrelated; see Lien et al., 2008). They were to press the key “z” with their left-index finger for related target words and the key “m” with their right-index finger for unrelated target words. Auditory feedback (a 22 kHz tone) was presented 100 ms after incorrect responses and silence lasted for 100 ms after correct responses. Immediately after the feedback, the next trial began with the fixation display for 1,200 ms.

The location of the target word was fixed throughout the whole experiment (the top row for half of the participants and the bottom row for the other half). Thus, participants were encouraged to endogenously allocate spatial attention to that target location. The prime word always appeared in the opposite location as the target word. The target word was either semantically related (50% of trials) or unrelated (50% of trials) to the category word. Each of the three prime-target conditions occurred equally often. In the *identical condition,* the prime word was the same as the target word. In the *same category condition*, the prime word was different from the target word but was from the same category. In the *different category condition*, the prime word was from a different category than the target word. As a consequence, the prime word belonged to the same category as the target on 2/3 of the trials. Each word appeared 4 times as the target for each participant, 2 times in the block when its category was selected (related) and 2 times when other categories were selected (unrelated).

The cue appeared 50% of the time in the prime word location (cued or attended prime condition) and 50% of the time in the target word location (uncued or unattended prime condition). Participants performed one practice block of 36 trials, followed by 9 experimental blocks of 72 trials each (a total of 648 experimental trials). They received a summary of their mean RT and accuracy at the end of each block. They were encouraged to take a break before beginning the next block.

Results

Trials were excluded from analysis if the RT was less than 100 ms or greater than 2,000 ms (0.28% of the trials). Error trials were also excluded from RT analyses. Table 1 shows the resulting mean RT and PE. Although we report the overall data analysis for the sake of completeness, note that our experimental logic rests specifically on the identity priming effect (see Equation 1) and the semantic priming effect (see Equation 2). The between-subject factor was target location (top vs. bottom), whereas the within-subject factors were prime cuing condition (cued vs. uncued), prime-target relationship (identical, same category, or different category), and target relatedness (related vs. unrelated). An analysis of variance (ANOVA) was performed, with the *p* values being adjusted using the Greenhouse-Geisser epsilon correction for non-sphericity, where appropriate. An alpha level of .05 was set for determining statistical significance.

Overall Data Analyses. The RT analyses revealed an overall priming effect: RT was shorter when the prime and the target were identical (593 ms) or from the same category (595 ms) than when they were from different categories (603 ms), $F(2, 116) = 17.79$, $p < .0001$, $\eta^2_p = .23$. Importantly, however, this effect interacted with prime cuing condition, $F(2, 116) = 19.84$, $p < .0001$, $\eta^2_p = .25$. We will defer detailed discussion of this interaction until the sections on Identity Priming Effects and Semantic Priming Effects below. The data analyses also revealed that RT was 40 ms shorter when the target was related to the category word (577 ms) than when it was unrelated (617 ms), $F(1, 58) = 93.97$, $p < .0001$, $\eta^2_p = .62$. No other effects were significant. In particular, there was no main effect of either target location or prime cuing condition.

Similar results were obtained in the PE data. Mean PE was smaller when the prime word

and the target word were identical (.077) or from the same category (.081) than when they were from different categories (.086), $F(2, 116) = 3.18$, $p < .05$, $\eta^2_p = .05$. As in the RT data, this effect was modulated by prime cuing condition, $F(2, 116) = 5.42$, $p < .01$, $\eta^2_p = .09$ (see detailed discussion under Identity Priming Effects and Semantic Priming Effects below). The three-way interaction between target location, target relatedness, and prime-target relationship was also significant, $F(2, 116) = 3.27$, $p < .05$, $\eta^2_p = .002$. When the target word was on the top location, the PE was relatively small when the target was an unrelated word for all three prime-target conditions. When the target word was on the bottom location, the PE was smaller for unrelated target words only for the identical and different category conditions (see Table 1).

<u>Identity Priming Effects.</u> To assess the identity priming effect, we included only the data from the identical condition and different category condition. The ANOVA was performed on RT and PE with the factors prime cuing condition (cued vs. uncued) and prime-target relationship (identical vs. different category). The overall identity priming effect on RT was 10 ms, $F(1, 58) = 33.83$, $p < .0001$, $\eta^2_p = .37$. Most importantly, the identity priming effect was obtained for cued primes (with a 95% confidence interval of 20 ± 6 ms) but not for uncued primes (0 ± 4 ms), $F(1, 58) = 30.77$, $p < .0001$, $\eta^2_p = .91$. Simple main effect analyses confirmed that the identity priming effect was significant for the cued prime condition, $F(1, 58) = 48.08$, $p < .0001$, $\eta^2_p = .45$, but not for the uncued prime condition, $F < 1.0$.

The PE data show a similar pattern as the RT data. The overall identity priming effect on PE was .009, $F(1, 58) = 6.43$, $p < .05$, $\eta^2_p = .10$; the PE was smaller when the prime and the target words were identical (.076) than when they were from different categories (.086). As in the RT data, the identity priming effect was obtained for the cued prime condition (.018 ± .011, using a 95% confidence interval) but not for the uncued prime condition (0 ± .008), $F(1, 58) =$

8.25, $p < .01$, $\eta^2_p = .13$. Simple main effect analyses again confirmed that the identity priming effect was significant for cued primes, $F(1, 58) = 10.97$, $p < .01$, $\eta^2_p = .16$, but not for uncued primes, $F < 1.0$.

Semantic Priming Effects. In addition to the identity priming effect, we also examined the semantic priming effect. We included data from the same and different category conditions only. The ANOVA was performed on RT and PE with the factors of prime cuing condition (cued vs. uncued) and prime-target relationship (same category vs. different category). The overall semantic priming effect on RT was 8 ms, $F(1, 58) = 17.96$, $p < .0001$, $\eta^2_p = .24$; RT was shorter when the prime and the target were from the same category (595 ms) than from different categories (603 ms). RT for the target word was faster when the prime was uncued (597 ms) than when it was cued (602 ms), $F(1, 58) = 10.30$, $p < .01$, $\eta^2_p = .15$. Most importantly, a substantial semantic priming effect was obtained for the cued prime condition (13 ± 5 ms, using a 95% confidence interval) but not for the uncued prime condition (3 ± 4 ms), $F(1, 58) = 10.30$, $p < .01$, $\eta^2_p = .15$. Simple main effect analyses confirmed that the semantic priming effect was significant for cued primes, $F(1, 58) = 24.83$, $p < .0001$, $\eta^2_p = .30$, but not for uncued primes, $F(1, 58) = 1.18$, $p = .2829$, $\eta^2_p = .02$.

In the PE data, the semantic priming effect was obtained for the cued prime condition (with a 95% confidence interval of .014 ± .011) but not for the uncued prime condition (-.004 ± .009), $F(1, 58) = 7.41$, $p < .01$, $\eta^2_p = .11$. Simple main effect analyses confirmed that the semantic priming effect was significant for cued primes, $F(1, 58) = 6.23$, $p < .05$, $\eta^2_p = .10$, but not for uncued primes, $F < 1.0$. No other effects were found to be significant.

Discussion

Experiment 1 evaluated whether unattended words could be processed sufficiently to

produce priming effects when each word was presented only occasionally. We used a large set of 162 words, each presented as a target only 4 times during an experimental session. As in Lachter et al. (2004, 2008), we took several steps to minimize attentional slippage to the prime words and thus control the allocation of the spatial attention (short presentation, mask, and a cue). After taking these precautions, we found both identity priming effect and semantic priming effect only when the prime word was attended (i.e., cued), not when it was unattended (i.e., uncued).

Because the prime word belonged to the same category (both identical and same category conditions) as the target on 2/3 of the trials, there might appear to have been an incentive for participants to use the primes. This view would predict both identity priming effect and semantic priming effect, even when the prime was uncued. Our findings were inconsistent with this prediction. The reason might be that our primes were presented so briefly (50 ms) that participants were typically not aware of them. The findings suggest that the visual words received little semantic activation in the absence of the spatial attention. They also indicate that Lachter et al.'s (2004) findings from the lexical-decision paradigm generalize to the categorization paradigm.

## Experiment 2

Experiment 1 yielded no evidence that semantic activation of unattended words occurs. Nevertheless, it is possible that spatial attention is less necessary when the words have a high baseline level of activation (as for important, expected, or frequently presented words). That is, repeated presentation of a small set of words might boost baseline activation of word nodes in lexical memory and thus facilitate word reading without spatial attention.

To address this issue, Experiment 2 reduced the set of words from 162 to only 8. Each

word was now presented 80 times per participant (compared to 4 times per participant in Experiment 1). As in Experiment 1, our main interest was whether the prime word can produce identity priming effects and semantic priming effects in the absence of the spatial attention.

## Method

Participants. There were new 72 participants, drawn from the same participant pool as in Experiment 1. Their mean age was 19 years, with a range of 18 to 38 years. They were all native English speakers and had normal or corrected-to-normal vision. As in Experiment 1, all participants demonstrated normal color vision using the Ishihara color test.

Apparatus, Stimuli, and Procedure. The tasks, stimuli, and equipment were the same as in Experiment 1, except that each participant received only one category containing 4 related words and 4 unrelated words drawn from other categories throughout the whole experimental session. We used the same categories as in Experiment 1; each category was used equally often across participants. In addition, each participant received 10 blocks of 64 trials each (one practice block and 9 experimental blocks).

## Results

The data analysis was similar to that of Experiment 1. Application of the RT cutoffs eliminated approximately 2.07% of trials. Table 2 shows the mean RT and PE.

Overall Data Analyses. The patterns obtained from overall data analyses were similar to those reported in Experiment 1. The RT analyses revealed that RT was shorter when the prime and the target were identical (539 ms) and when they were from the same category (544 ms) than when they were from different categories (554 ms), $F(2, 140) = 35.86$, $p < .0001$, $\eta^2_p = .34$. Most importantly, the interaction between prime cuing condition and prime-target relationship was again significant, $F(2, 140) = 38.77$, $p < .0001$, $\eta^2_p = .36$ (see discussion under Identity

Priming Effects, and Semantic Priming Effects below). RT was 11 ms shorter when the target was related to the category (540 ms) than when it was unrelated (551 ms), $F(1, 70) = 22.47$, $p < .0001$, $\eta^2_p = .24$. This effect also interacted with prime cuing condition. Mean RT was 4 ms shorter for cued primes than uncued primes when the target word was related to the category but was 3 ms slower when the target word was unrelated, $F(1, 70) = 7.39$, $p < .01$, $\eta^2_p = .10$.

The PE analyses revealed that PE was smaller when the prime and the target words were identical (.065) or from the same category (.062) than when they were from different categories (.068), $F(2, 140) = 16.67$, $p < .0001$, $\eta^2_p = .19$. The PE was smaller for uncued primes (.067) than cued primes (.073), $F(1, 70) = 4.40$, $p < .05$, $\eta^2_p = .06$. As with the RT data, the interaction between prime cuing condition and prime-target relationship was significant on PE, $F(2, 140) = 10.89$, $p < .001$, $\eta^2_p = .13$ (see discussion below). The PE was higher for the unrelated than the related target words in the identical condition (.068 vs. .061, respectively) but was lower in the same category condition (.059 vs. .066, respectively) and in the different category condition (.079 vs. .086, respectively), $F(2, 140) = 4.55$, $p < .05$, $\eta^2_p = .06$. The 3-way interaction between these variables and prime cuing condition was also significant, $F(2, 140) = 3.52$, $p < .05$, $\eta^2_p = .05$; a higher PE for the unrelated target word than the related target word was obtained only for cued primes in the identical condition (see Table 2).

Identity Priming Effects. The overall identity priming effect on RT was 15 ms, $F(1, 72) = 50.49$, $p < .0001$, $\eta^2_p = .42$; mean RT was shorter when the prime and target were identical (539 ms) than when they were from different categories (554 ms). Most importantly, the identity priming effect was obtained when the prime was cued (with a 95% confidence interval of 26 ± 6 ms) but not when it was uncued (3 ± 4 ms), $F(1, 70) = 56.09$, $p < .0001$, $\eta^2_p = .44$. Simple main effect analyses confirmed that the identity priming effect was significant for cued primes, $F$(1,

70) = 75.58, $p < .0001$, $\eta^2_p = .52$, but not for uncued primes, $F(1, 70) = 2.41$, $p = .1248$, $\eta^2_p = .03$.

The PE data were similar to the RT data. The overall identity priming effect on PE was .020, $F(1, 70) = 17.81$, $p < .0001$, $\eta^2_p = .20$; the PE was smaller when the prime and target were identical (.065) than when they were from different categories (.083). The PE for the target word was .013 smaller when the prime was uncued (.067) than when it was cued (.080), $F(1, 70) = 16.39$, $p < .0001$, $\eta^2_p = .19$. As in the RT data, the identity priming effect was obtained when the prime was cued (.033 ± .014, using the 95% confidence interval) but not when it was uncued (.002 ± .009), $F(1, 70) = 13.64$, $p < .001$, $\eta^2_p = .16$. Simple main effect analyses confirmed that the identity priming effect was significant for cued primes, $F(1, 70) = 21.29$, $p < .0001$, $\eta^2_p = .23$, but not for uncued primes, $F < 1.0$.

<u>Semantic Priming Effects.</u> As in Experiment 1, we also examined the semantic priming effect including only the data from the same and different category conditions. The overall semantic priming effect on RT was 10 ms, $F(1, 70) = 30.25$, $p < .0001$, $\eta^2_p = .30$; the RT was shorter when the prime and target were from the same category (544 ms) than from different categories (554 ms). RT for the target word was shorter when the prime was uncued (547 ms) than when it was cued (551 ms), $F(1, 70) = 7.39$, $p < .01$, $\eta^2_p = .10$, suggesting that the attended prime word slowed down the processing of the target word. Most importantly, a semantic priming effect was obtained when the prime word was cued (with a 95% confidence interval of 19 ± 5 ms) but not when it was uncued (1 ± 4 ms), $F(1, 70) = 42.17$, $p < .0001$, $\eta^2_p = .38$. Simple main effect analyses revealed that the semantic priming effect was significant for cued primes, $F(1, 70) = 65.01$, $p < .0001$, $\eta^2_p = .48$, but not for uncued primes, $F < 1.0$.

The PE data analyses revealed a similar pattern as in the RT data. The overall semantic

priming effect on PE was .020, $F(1, 70) = 21.60$, $p < .0001$, $\eta^2_p = .24$; the PE was smaller when the prime and target were from the same category (.062) than from different categories (.083). PE for the target word was smaller when the prime was uncued (.067) than when it was cued (.077), $F(1, 70) = 8.67$, $p < .01$, $\eta^2_p = .11$. Most importantly, the semantic priming effect was obtained when the prime was cued (with a 95% confidence interval of .039 ± .016) but not when it was uncued (.002 ± .010), $F(1, 70) = 13.13$, $p < .001$, $\eta^2_p = .16$. Simple main effect analyses confirmed that the semantic priming effect was significant for cued primes, $F(1, 70) = 23.96$, $p < .0001$, $\eta^2_p = .25$, but not for uncued primes, $F < 1.0$.

Discussion

The purpose of Experiment 2 was to examine whether semantic activation outside spatial attention is possible when words have a high baseline level of activation. Thus, we increased the activation of word nodes by repeatedly presenting the same small set of words throughout the whole experiment. Each participant received only one of the categories used in Experiment 1, and it consisted of only 4 related words and 4 unrelated words (compared to 9 categories of 162 related and 162 unrelated words in Experiment 1). Instead of repeating each word only 4 times per participant, as in Experiment 1, each word was now presented 80 times. This change decreased overall RT from 597 ms to 546 ms.

Despite the high frequency of presentation of the words, the priming effects were nearly identical to those of Experiment 1. The identity priming effect and the semantic priming effect on both RT and PE were still evident only when the prime was cued (attended), not when it was uncued (unattended). These findings suggest that spatial attention is needed for semantic activation even for words that are highly activated.

## Experiment 3

Experiment 3 took a further step to increase the baseline activation of the words by including only 4 words for each category (2 related and 2 unrelated). This modification brings us closer to Stroop studies, which typically use 4 color words within an experimental session (e.g., Lachter et al., 2008). Each word was now presented 160 times as the target word per participant, twice as often as in Experiment 2.

Method

Participants. There were 78 new participants, drawn from the same participant pool as in previous experiments. Their mean age was 20 years, with a range of 18 to 35 years. They were all native English speakers and had normal or corrected-to-normal vision. As in previous experiments, all participants passed the Ishihara color test.

Apparatus, Stimuli, and Procedure. The tasks, stimuli, and equipment were the same as in Experiment 2, except that each participant received only one category containing 2 related words and 2 unrelated words drawn from other categories. Each word was repeated 160 times throughout the whole experiment. Each participant received 10 blocks of 64 trials each (one practice block and 9 experimental blocks).

Results

The data analysis was similar to that of Experiment 2. Application of the RT cutoffs eliminated 0.51% of trials. Table 3 shows the resulting mean RT and PE.

Overall Data Analyses. The patterns obtained from the overall data analysis were similar to those reported in Experiment 2. RT was 11 ms shorter when the target was related to the category (490 ms) than when it was unrelated (498 ms), $F(1, 76) = 16.00$, $p < .0001$, $\eta^2_p = .17$. Unlike the previous experiments, the difference in RT between related and unrelated targets was significantly larger when the target appeared in the bottom location (difference = 13 ms) than

when it appeared in the top location (difference = 2 ms), $F(1, 76) = 8.24$, $p < .01$, $\eta^2_p = .10$.

Again, mean RT varied significantly across the identical (489 ms), same category (493 ms), and different category condition (501 ms), $F(2, 152) = 41.68$, $p < .0001$, $\eta^2_p = .35$. However, as in Experiments 1 and 2, the interaction between prime cuing condition and prime-target relationship was significant, $F(2, 152) = 31.05$, $p < .0001$, $\eta^2_p = .29$ (see discussion under Identity Priming Effects, and Semantic Priming Effects below). Furthermore, mean RT was 4 ms faster for cued primes than uncued primes when the target word was related to the category but was 1 ms slower when the target word was unrelated, $F(1, 76) = 12.82$, $p < .001$, $\eta^2_p = .14$.

The PE analyses revealed that PE was higher when the prime and target were from different categories (.071) than when they were from the same category (.052) or identical (.050), $F(2, 152) = 25.87$, $p < .0001$, $\eta^2_p = .25$. The PE was higher for the related target word (.062) than for the unrelated target word (.054), $F(1, 76) = 5.83$, $p < .05$, $\eta^2_p = .07$. As with the RT data analyses, the interaction between prime cuing condition and prime-target relationship was significant, $F(2, 152) = 18.70$, $p < .001$, $\eta^2_p = .20$ (see below).

The difference in PE between the unrelated and related target words was larger in the different category condition (.078 vs. .063, respectively) than in the same category condition (.054 vs. .051, respectively) and the identical condition (.053 vs. .047, respectively), $F(2, 152) = 3.25$, $p < .05$, $\eta^2_p = .04$. The 4-way interaction between target location (top vs. bottom), prime cuing condition (cued vs. uncued), prime-target relationship (identical, same category, or different category), and target relatedness (related vs. unrelated) was significant, $F(2, 152) = 3.88$, $p < .05$, $\eta^2_p = .05$. For both related and unrelated target words, the PE was smaller for cued primes than for uncued primes in the identical condition but was larger in the different category condition. However, the results were mixed in the same category condition, depending on the

target location (see Table 3).

Identity Priming Effects. As in the previous experiments, we examined the identity priming effect including the data from the identical condition and different category condition. The overall identity priming effect on RT was 12 ms, $F(1, 76) = 74.56$, $p < .0001$, $\eta^2_p = .50$; the RT was shorter when the prime and target were identical (489 ms) than when they were from different categories (501 ms). Most importantly, a substantial identity priming effect was obtained when the prime was cued (with a 95% confidence interval of 21 ± 4 ms) but not when it was uncued (3 ± 3 ms), $F(1, 76) = 66.69$, $p < .0001$, $\eta^2_p = .47$. Simple main effect analyses confirmed that the identity priming effect was significant for cued primes, $F(1, 76) = 99.26$, $p < .0001$, $\eta^2_p = .57$. The effect was small for uncued primes and only approached significance, $F(1, 76) = 3.64$, $p = .0601$, $\eta^2_p = .05$.

The PE data revealed an overall identity priming effect of .021, $F(1, 76) = 39.17$, $p < .0001$, $\eta^2_p = .34$; the PE was smaller when the prime and target were identical (.050) than when they were from different categories (.071). As in the RT data, the identity priming effect on PE was obtained when the prime was cued (.038 ± .010 at the 95% confidence interval) but not when it was uncued (.004 ± .008), $F(1, 76) = 33.33$, $p < .001$, $\eta^2_p = .30$. Simple main effect analyses confirmed that the identity priming effect was significant for cued primes, $F(1, 76) = 58.55$, $p < .0001$, $\eta^2_p = .44$, but not for uncued primes, $F < 1.0$.

Semantic Priming Effects. The RT data analyses for the semantic priming effect (including only the data from the same and different category conditions) showed that the overall semantic priming effect on RT was 8 ms, $F(1, 76) = 44.95$, $p < .0001$, $\eta^2_p = .37$; the RT was shorter when the prime and target were from the same category (493 ms) than from different categories (501 ms). RT for the target word was 3 ms shorter when the prime was uncued (495

ms) than when it was cued (498 ms), $F(1, 76) = 5.32$, $p < .05$, $\eta^2_p = .07$, suggesting that the attended prime word slowed down the processing of the target word. Most importantly, the semantic priming effect was obtained when the prime was cued (with a 95% confidence interval of 14 ± 3 ms) but not when it was uncued (1 ± 3 ms), $F(1, 76) = 26.20$, $p < .0001$, $\eta^2_p = .26$. Simple main effect analyses confirmed that the semantic priming effect was significant for cued primes, $F(1, 76) = 65.63$, $p < .0001$, $\eta^2_p = .43$, but not for uncued primes, $F < 1.0$.

The PE data analyses revealed similar patterns as in the RT data. The overall semantic priming effect on PE was .019, $F(1, 76) = 32.28$, $p < .0001$, $\eta^2_p = .04$; the PE was smaller when the prime and target were from the same category (.052) than from different categories (.071). PE for the target word was smaller when the prime was uncued (.056) than when it was cued (.067), $F(1, 76) = 14.64$, $p < .001$, $\eta^2_p = .16$. Most importantly, the semantic priming effect obtained when the prime was cued (with a 95% confidence interval of .029 ± .009) was much larger than that obtained when it was uncued (.008 ± .007), $F(1, 76) = 18.78$, $p < .0001$, $\eta^2_p = .20$. Simple main effect analyses confirmed that the semantic priming effect was significant for cued primes, $F(1, 76) = 42.98$, $p < .0001$, $\eta^2_p = .36$. Although the effect was significant for uncued primes, $F(1, 76) = 4.51$, $p < .05$, $\eta^2_p = .06$, it was quite small.

Discussion

Experiment 3 used only 4 words (2 related and 2 unrelated from each category), which were repeated 160 times for each participant. Note that this frequency is similar to Stroop experiments, which typically repeat the same four color word stimuli (red, green, blue, and yellow). This change further reduced overall RT, from 546 ms in Experiment 2 to only 494 ms.

Even when the words were repeated with such a high frequency (twice as often as in Experiment 2), the identity priming effect and the semantic priming effect were evident only

when the prime was cued (attended), not when it was not (unattended). Replicating both Experiments 1 and 2, these findings suggest that spatial attention is needed for semantic activation even for familiar and expected words.

## General Discussion

The present study examined whether semantic activation is possible for words presented outside of spatial attention. We proposed a variant of attention theory in which such automatic semantic activation is possible when words have a high baseline level of activation, as would occur for recently presented words, important words (e.g., one's own name), or words that are expected within that context. Such a mechanism is not only plausible but would also help to explain recent controversies in the literature. Previous work using a lexical-decision paradigm, in which each word was presented only once, has suggested that semantic activation is not possible for unattended words (see e.g., Chiappe et al., 1996; Dark et al., 1985; Lachter et al., 2004; Stolz & McCann, 2000; Stolz & Neely, 1995). Previous studies using the Stroop paradigm, however, have suggested that it is possible (e.g., Brown et al., 2002; Lachter et al., 2008; but see Besner et al., 1997, for a single colored letter version of the Stroop paradigm). These Stroop studies typically involved only 4 or fewer color words, presented repeatedly throughout the experiment. The high frequency of presentation might have minimized the need for spatial attention in semantic activation.

To evaluate this attractive hypothesis, Experiment 1 used a large set of words (162), each repeated only 4 times for each participant, whereas Experiments 2 and 3 used a small set of words (8 vs. 4, respectively) repeated 80 and 160 times, respectively. We used a categorization paradigm, in which participants indicated whether the target word belonged to a pre-specified category. Our methodology emphasized the need to control the locus of spatial attention and

prevent slippage to “unattended” prime words (e.g., Lachter et al., 2004). We presented the targets and primes in a fixed location for each participant, so there was no reason to endogenously attend the primes. In addition, the prime word was presented for only 50 ms, followed by a mask, so that it did not have time to capture attention prior to being extinguished. We also used a rapid sequence of 3 non-words as a cue to capture spatial attention. In the unattended prime condition, we used these cues to further ensure the allocation of attention to the target location and not the prime location. In the attended prime condition, we used these cues to attract attention to the prime, to verify that – when attended – primes are sufficiently visible to produce substantial priming effects.

Summary of Experimental Findings

In Experiment 1, where each word was repeated only 4 times per participant, both the identity priming effect and the semantic priming effect were obtained only when the prime was cued (attended), not when it was uncued (unattended). Similar results were obtained even when the frequency of word repetitions dramatically increased in Experiments 2 (80 repetitions per session) and 3 (160 repetitions). An additional data analysis with experiment as a between-subject variable showed that overall RT decreased sharply as the frequency of word repetitions increased, $F(2, 207) = 46.33$, $p < .0001$, $MSE$ =181,383; mean RT was 597, 546, and 494 ms for Experiments 1, 2, and 3, respectively. This result confirms that manipulating the frequency of word repetitions does have a substantial effect on performance, presumably by increasing the baseline activation of the relevant word representations.

For cued (i.e., attended) primes, the overall identity priming effect, averaged across all three experiments, was 22 ± 3 ms (95% confidence interval) and the semantic priming effect was 15 ± 2 ms. For uncued (i.e., unattended) primes, however, both the identity and semantic

priming effects were only 2 ± 2 ms. We conducted between-experiment analyses on the identity and semantic priming effects, including the variables of experiment and prime cuing condition. The interaction between these variables was not significant for the identity priming effect, $F < 1.0$, or for the semantic priming effect, $F(2, 207) = 2.43$, $p = .09$, $\eta^2_p = .26$.

Two main conclusions can be drawn from these results. First, the absence of priming effects from unattended words in Experiment 1 shows that this phenomenon is not just a quirk of the lexical-decision paradigm (Lachter et al., 2004) and further supports the conclusion that semantic activation of infrequently presented words requires spatial attention. This result held even though the categorization paradigm encourages participants to think about a particular category and generate expectancies for words within that category.

Second, and most importantly, these results argue against the hypothesis that semantic activation outside spatial attention is possible when word representations have a high baseline level of activation (due to being recently presented many times or due to being expected). This account was inspired by recent findings using the Stroop paradigm (Lachter et al., 2008) and by Treisman's (1960) attenuation model. According to that model, unattended stimuli are attenuated but not completed filtered out. Thus, it seemed highly plausible that frequently presented and expected words, but not infrequently presented and unexpected words, could break through the attentional filter and be identified. Nevertheless, the present data provided no evidence for such an account.

<u>What is Special about the Stroop Paradigm?</u>

Interestingly, a recent Stroop-naming study by Lachter et al. (2008; see also Brown et al., 2002) provided evidence that word identification sometimes occurs outside the focus of spatial attention. Color words produced significant Stroop effects even when measures similar to those

taken in the current study were used to assure they were unattended. In that study, a small set of color words was repeatedly numerous times throughout the experiment (4 words repeated about 122 times per participant in Experiment 1). The frequency of word presentations was nearly identical to the present Experiment 3, in which 4 words were repeated 160 times per session. Why was semantic activation outside spatial attention apparently possible in their study but not in the present study? It appears that whether the words are highly activated is not the primary cause for the semantic activation to occur outside spatial attention.

One possibility is that domain of processing on the target determines the demand for spatial attention. For instance, in the Stroop color-naming paradigm of Lachter et al. (2008), the target was a color bar and the distractor was a color word. Perhaps the processing of the color bar requires little spatial attention, thus freeing spatial attention to move somewhere other than the target location (e.g., Andersen, Müller, & Hillyard, 2009). In contrast, both the prime and target in our categorization paradigm were words. Perhaps reading words require spatial attention, thus limiting the ability of spatial attention to wander to the location of the prime word. This hypothesis would also explain the lack of evidence for semantic activation without spatial attention in Lachter et al.'s (2004) study, which used a lexical-decision paradigm (word vs. nonword targets). Being aware of this issue, Lachter et al. (2008) placed a colored border around the color bar. Their goal was to encourage a tight focus of spatial attention, though it is unclear whether this effort was successful.

Although our hypothesis that domain of processing on the target determine the demand for spatial attention seems similar to the domain-specific processing hypothesis (e.g., Allport, 1980; Chiappe et al., 1996; Finkbeiner & Forster, 2008), there is a subtle difference. According to domain-specific processing, processing the target at the word or letter level makes demands on

specific resources, which are then not available to other stimuli. In the lexical-decision paradigm, for example, word processing on the target might utilize the resources needed to process the word primes. In the Stroop paradigm (e.g., Brown et al., 2002; Lachter et al., 2008), however, processing the target at the color level might not draw on the same resources that are required for word recognition. This domain-specific processing can explain some of the findings, but seems to make an incorrect prediction for the present study. Because the target and the prime need the same word processing resources, there should be no priming effects for both cued and uncued primes, contrary to our findings.

The second possibility is that the absence of priming effects from unattended words in the present study is due not only to the absence of spatial attention, but also to an inhibitory mechanism specific to words. Perhaps when the target task involves word processing (as in the present study and Lachter et al., 2004), the attentional system somehow prevents irrelevant stimuli from gaining access to word recognition mechanisms. In the Stroop paradigm, meanwhile, the target task typically involves naming ink color. As a consequence, there might be less need for inhibitory mechanisms to inhibit semantic processing of irrelevant stimuli.

A third, somewhat related, explanation for the discrepancy in the findings between the Stroop paradigm and the categorization paradigm concerns the response competition activated by the irrelevant stimuli. In the Stroop paradigm, the irrelevant stimuli were typically the color words. Processing of individual letters at the phonetic level would be sufficient to activate compatible or incompatible response for the target stimuli (e.g., phonetic activation of the letter "R" in word "RED" would make it easier to say "RED" for the target color red and more difficult to say "GREEN" for the target color green). In the current categorization paradigm, however, the related prime words and responses for the target words do to share phonetics, only

semantics. To address this possibility, Lachter et al. (2008) used color-associated words (e.g., "LEMON" for yellow, "SKY" for blue) as irrelevant stimuli in their Experiment 3, because such words do not necessarily share any phonetics with the target color names. These stimuli produced only a 4-ms Stroop-like effect (albeit statistically significant), not substantially greater than the effects of the unattended primes in the present study. All of the explanations discussed above are logically possible and consistent with the available data; therefore, further studies will be needed to distinguish between them

Evaluation of Attenuation Theories

We hypothesized that elevating the baseline activation of words (e.g., due to frequent repetition, expectation, or importance) would allow for more automatic semantic activation in the absence of spatial attention. As noted above, this hypothesis is related to, but distinct from, Treisman's (1960) attenuation theory. The hypothesis seemed plausible a priori and could also explain why people sometimes notice important words (e.g., their own name; the "cocktail party effect") or expected words in an unattended channel (e.g., Treisman, 1960). It also would help explain why there is more evidence of word processing without attention in Stroop studies (where the same four color words/concepts are highly active) than in lexical-decision studies (where each word is typically presented only once). Nevertheless, the present results provide no evidence for the claim that repetition or expectancy facilitates automatic semantic activation.

It is still unclear why words that are familiar (such as one's own name) or expected within a particular context are often detected even when attention is allocated somewhere else. For example, Moray (1959) noted that when shadowing one channel (e.g., the left ear) people sometimes notice their own name in the other (supposedly unattended) channel. Also, Treisman (1960) found that people told to shadow one channel would occasionally switch to the other

channel if the content switched ears. As discussed by Lachter et al. (2004), it is possible that these examples do not reflect leakage through the attention filter, but rather reflect slippage of attention (see also Conway, Cowan, & Bunting, 2001). That is, participants might occasionally allocate their attention to the supposedly unattended channel and only at that point begin to process the content semantically. In Treisman (1960), for example, participants followed the message to the irrelevant ear only 6% of the time. It is easy to imagine occasional slippage of this modest magnitude, perhaps induced by the lack of coherence of the text in the to-be-shadowed ear. In summary, it might be the case the words with elevated baselines (e.g., frequently repeated) cannot be processed without spatial attention, but are more likely to be remembered if they do receive some spatial attention.

Summary

The present study provides further evidence that word reading depends critically on spatial attention (e.g., Besner et al., 1997; Chiappe et al., 1996; Dark et al., 1985; Lachter et al., 2004; Stolz & Besner, 1999; Stolz & McCann, 2000; Stolz & Neely, 1995). One notable finding is that unattended words were not processed sufficiently to prime the categorization response to the target, even when those words were in the target set (consisting of only 4 words in Experiment 3) and recently presented with a high frequency (160 repetitions in Experiment 3). Although it is highly plausible that word expectancy and word repetition would strongly reduce the need for spatial attention, clearly they did not. Further research is needed to determine why the Stroop paradigm sometimes produces evidence of word reading outside the focus of attention (e.g., Brown et al., 2002; Lacther et al., 2008) when other paradigms do not.

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**Footnote**

1. Eighteen out of the 20 categories, excluding the categories “Color” and “Fish”, from Lien et al.’s (2008) study were used in Experiment 1. There were 17 related words in each category in Lien et al.’s study, but we added one more related word per category (for a total of 18 related words) in the present study.

Table 1.

Response Times (RT; in ms) and Proportion of Errors in Parentheses in Experiment 1 as a Function of Target Location (Top and Bottom), Prime Cuing Condition (Cued and Uncued), Prime-Target Relationship (Identical, Same Category, and Different Category), and Target Relatedness (Related vs. Unrelated).

| Prime Cuing Condition | Prime-Target Relationship | | | | | |
|---|---|---|---|---|---|---|
| | Identical | | Same Category | | Different Category | |
| | Target Related | Target Unrelated | Target Related | Target Unrelated | Target Related | Target Unrelated |
| Target on the Top | | | | | | |
| Cued | 572 (.084) | 608 (.064) | 585 (.093) | 616 (.067) | 594 (.096) | 634 (.087) |
| Uncued | 582 (.085) | 622 (.091) | 584 (.100) | 616 (.073) | 582 (.086) | 618 (.072) |
| Target on the Bottom | | | | | | |
| Cued | 562 (.075) | 610 (.067) | 567 (.069) | 613 (.078) | 583 (.097) | 621 (.084) |
| Uncued | 575 (.081) | 613 (.065) | 570 (.086) | 611 (.081) | 572 (.082) | 621 (.083) |

Table 2.

Response Times (RT; in ms) and Proportion of Errors in Parentheses in Experiment 2 as a Function of Target Location (Top and Bottom), Prime Cuing Condition (Cued and Uncued), Prime-Target Relationship (Identical, Same Category, and Different Category), and Target Relatedness (Related vs. Unrelated).

| Prime Cuing Condition | Prime-Target Relationship | | | | | |
|---|---|---|---|---|---|---|
| | Identical | | Same Category | | Different Category | |
| | Target Related | Target Unrelated | Target Related | Target Unrelated | Target Related | Target Unrelated |
| Target on the Top | | | | | | |
| Cued | 533 (.055) | 548 (.068) | 539 (.056) | 554 (.053) | 558 (.097) | 578 (.092) |
| Uncued | 543 (.060) | 556 (.064) | 543 (.067) | 562 (.065) | 549 (.072) | 561 (.066) |
| Target on the Bottom | | | | | | |
| Cued | 522 (.053) | 535 (.077) | 530 (.068) | 541 (.055) | 546 (.106) | 559 (.091) |
| Uncued | 541 (.076) | 538 (.065) | 540 (.072) | 542 (.061) | 538 (.070) | 542 (.065) |

Table 3.

Response Times (RT; in ms) and Proportion of Errors in Parentheses in Experiment 3 as a Function of Target Location (Top and Bottom), Prime Cuing Condition (Cued and Uncued), Prime-Target Relationship (Identical, Same Category, and Different Category), and Target Relatedness (Related vs. Unrelated).

| Prime Cuing Condition | Prime-Target Relationship | | | | | |
|---|---|---|---|---|---|---|
| | Identical | | Same Category | | Different Category | |
| | Target Related | Target Unrelated | Target Related | Target Unrelated | Target Related | Target Unrelated |
| Target on the Top | | | | | | |
| Cued | 476 (.045) | 486 (.051) | 486 (.055) | 489 (.059) | 499 (.106) | 504 (.077) |
| Uncued | 490 (.073) | 490 (.054) | 491 (.061) | 489 (.058) | 493 (.076) | 491 (.064) |
| Target on the Bottom | | | | | | |
| Cued | 479 (.042) | 494 (.036) | 487 (.055) | 502 (.041) | 501 (.073) | 515 (.071) |
| Uncued | 494 (.055) | 501 (.045) | 490 (.045) | 508 (.046) | 496 (.060) | 504 (.042) |

**Figure Captions**

Figure 1. An example event sequence for the uncued prime condition of Experiment 1. In this example, the prime and the target words belonged to the same category (e.g., "Sports"), which was named prior to each block. The target was always presented in the bottom location. Trials began with a fixation cross, followed by a mask. Three non-words, alternating in uppercase and lowercase, appeared in the location opposite to the subsequent prime word (because the condition shown is the uncued condition). The prime word was always printed in lowercase, whereas the target word was always printed in uppercase.

Figure 2. Mean response times for cued and uncued primes in Experiment 1 as a function of prime-target relationship (identical, same category, or different category). Panel A shows the mean response times for the identical condition and the different category condition (the difference between these conditions is the identity priming effect). Panel B shows the mean response times in the same category condition (excluding the identical trials) and the different category condition (the difference between these conditions is the semantic priming effect). Error bars represent the standard error of the mean.

Figure 3. Mean response times for cued and uncued primes in Experiment 2 as a function of prime-target relationship (identical, same category, or different category). Panel A shows the mean response times for the identical condition and the different category condition (the difference between these conditions is the identity priming effect). Panel B shows the mean response times in the same category condition (excluding the identical trials) and the different category condition (the difference between these conditions is the semantic priming effect). Error bars represent the standard error of the mean.

Figure 4. Mean response times for cued and uncued primes in Experiment 3 as a function of

prime-target relationship (identical, same category, or different category). Panel A shows the mean response times for the identical condition and the different category condition (the difference between these conditions is the identity priming effect). Panel B shows the mean response times in the same category condition (excluding the identical trials) and the different category condition (the difference between these conditions is the semantic priming effect). Error bars represent the standard error of the mean.

Figure 1

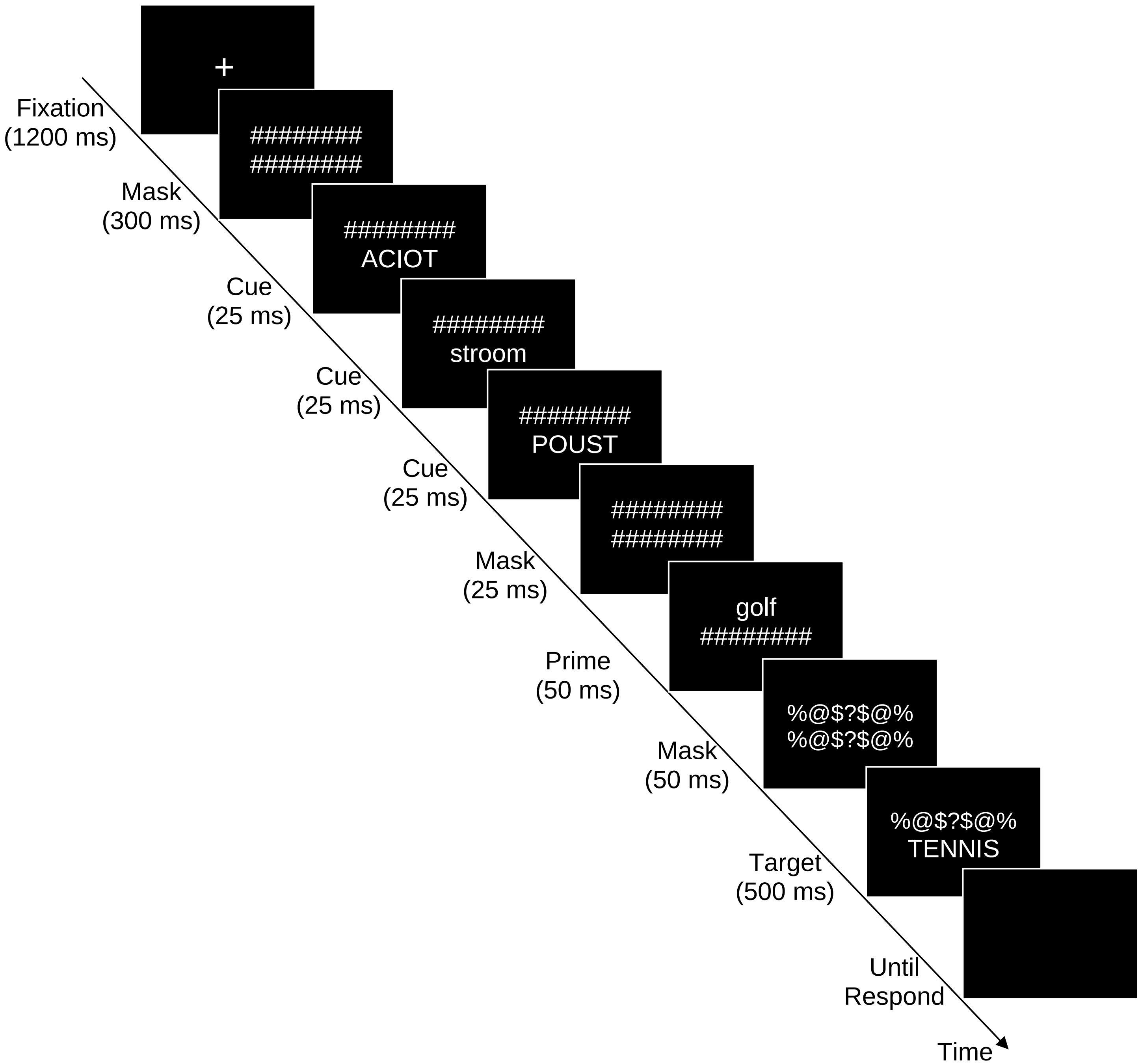
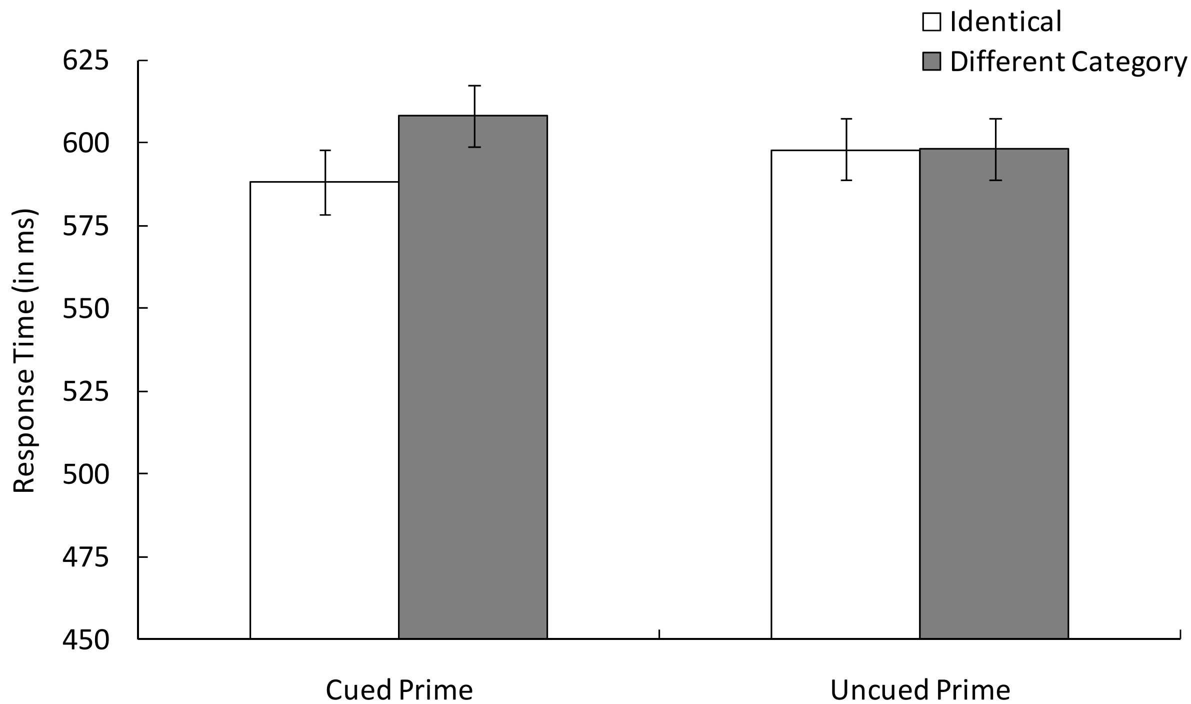

+
Fixation
(1200 ms)
########
########
Mask
(300 ms)
########
ACIOT
Cue
(25 ms)
########
stroom
Cue
(25 ms)
########
POUST
Cue
(25 ms)
########
########
Mask
(25 ms)
golf
########
Prime
(50 ms)
%@$?$@%
%@$?$@%
Mask
(50 ms)
%@$?$@%
TENNIS
Target
(500 ms)
Until
Respond
Time

Figure 2

**Panel A**




**Panel B**

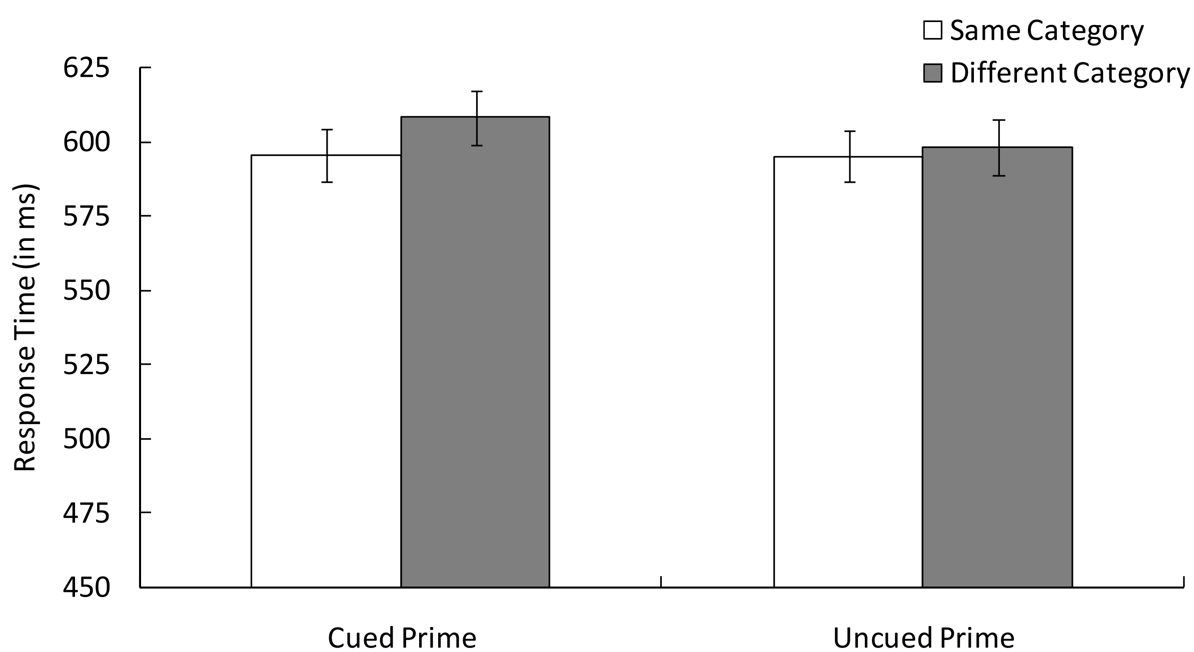


Figure 3

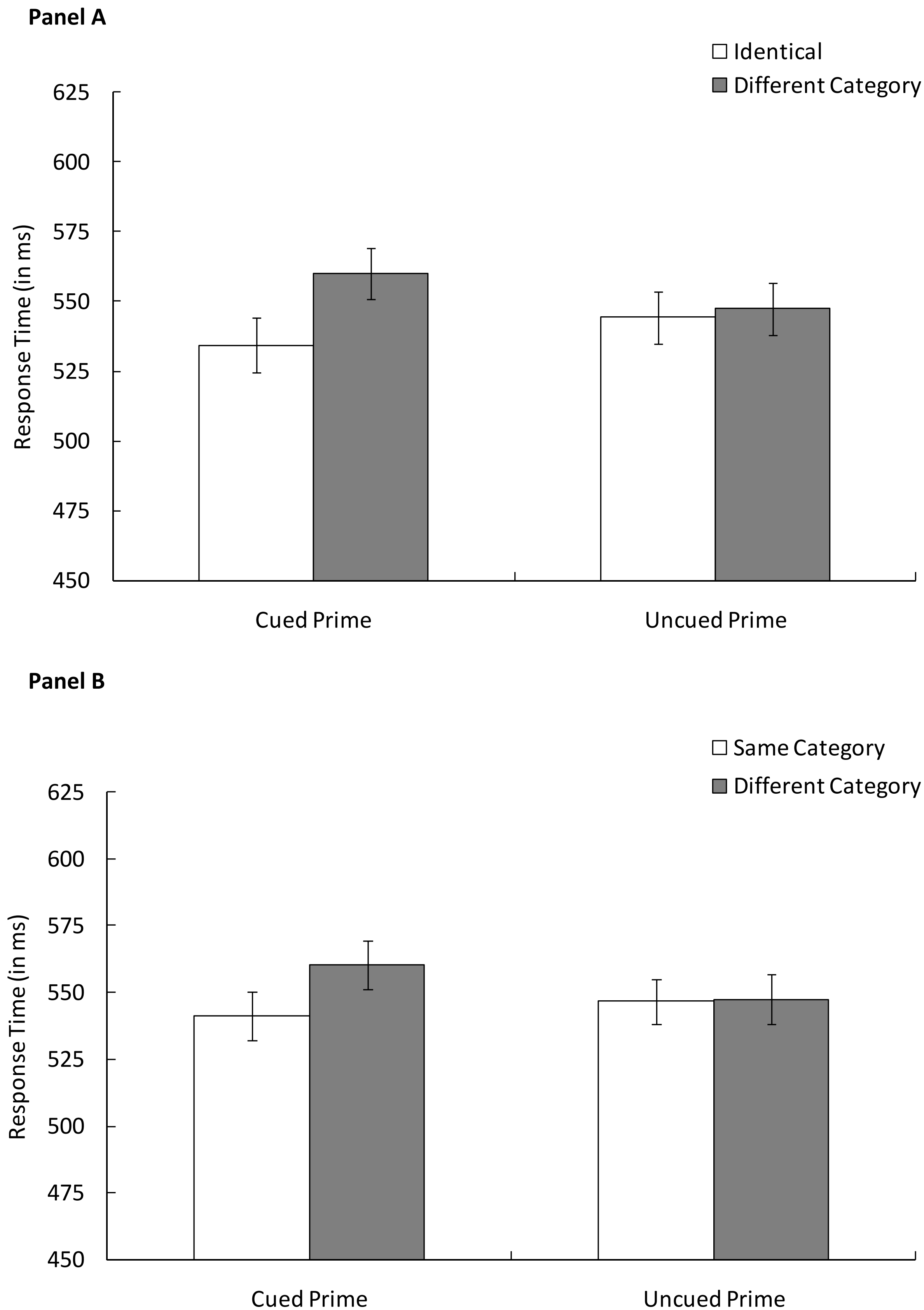
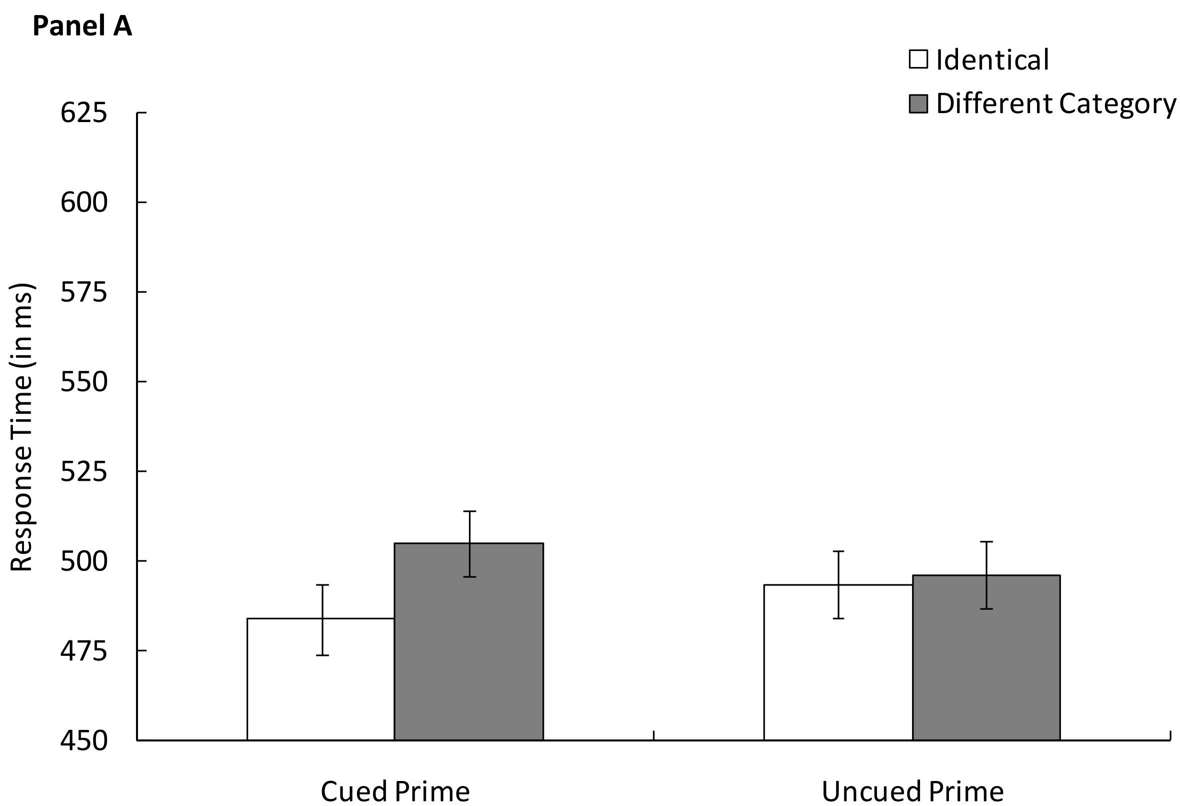
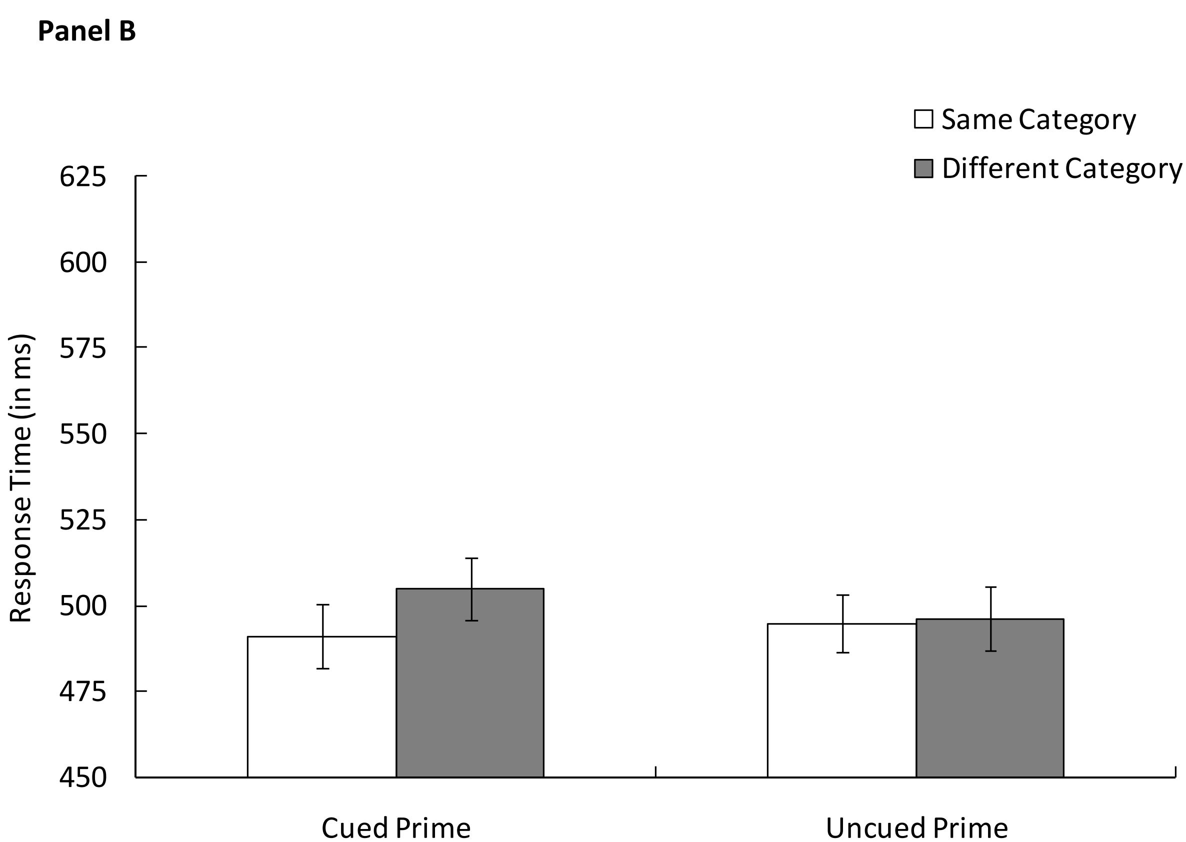

Panel A
Identical
Different Category
625
600
575
550
525
500
475
450
Response Time (in ms)
Cued Prime
Uncued Prime
Panel B
Same Category
Different Category
625
600
575
550
525
500
475
450
Response Time (in ms)
Cued Prime
Uncued Prime

Figure 4


Panel A
Identical
Different Category
625
600
575
550
525
500
475
450
Response Time (in ms)
Cued Prime
Uncued Prime


Panel B
Same Category
Different Category
625
600
575
550
525
500
475
450
Response Time (in ms)
Cued Prime
Uncued Prime